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An Approach for Quality Assessment and Efficiency of a Web-Based System for Distance Learning

Elisaveta Trichkova, Krasimira Stoilova**

** Institute of Information and Communication Technologies, 1113 Sofia*
Emails: elisaveta@hsi.iccs.bas.bg k.stoilova@hsi.iccs.bas.bg

Abstract: *The aim of this paper is to propose an approach for quality assessment and efficiency of the web-based system for distance learning. This system has useful options for on-line creation and use of Web-based courses by other medical disciplines in Medical University – Sofia. The results of the assessment will be used to improve the functionality of the processes in the system to meet the user requirements.*

Keywords: *Web-based system, distance learning, software quality assessment, efficiency.*

1. Introduction

The progress of digital technologies and computerization of traditional media presents challenges to traditional schools and universities.

As described in [1], the choices of pedagogy and technology are complex. If the students are offered regular teaching and learning sources (books, lectures, face-to-face seminars) together with theory driven e-Learning scenarios that do not correspond to their real needs, it is obvious that they are going to prefer the well-known means for learning and disregard the new ones. For development of efficient

e-Learning applications, new scenario-based approaches incorporating real-world practical experiences are much more significant. An approach to active learning facilitated by the use of semantic technologies on the example of iconographical objects is presented in [2].

The quality assessment and efficiency of the web-based educational systems is essential both in its overall analysis and improvement.

The Web-based system is designed for teachers and students from different medical disciplines in the Medical University – Sofia (MUS) to facilitate them in uploading traditional and interactive teaching resources. This is important for the contemporary students, named "net generation" [3]. The system implements a problem-solving oriented learning in Medical Biochemistry and it is assessed as a successful new pedagogical model [4].

The whole system is based on open source products and developed according to the specifications and requirements of the Medical University – Sofia.

2. Approach for assessing the quality and efficiency of the system

2.1. Overview

Educational websites are studied in many different perspectives. Z h a n g and D r a n [5] developed a theoretical framework for evaluating the website quality from a user satisfaction perspective. Others concentrated on some specific features of websites. For example, L a u t e n b a c h et al. [6] developed a framework to measure the usability of websites, while Y o o and J i n [7] investigated and evaluated the design of the university websites. Other researchers take into account other features for assessing the university websites. O s b o r n e and R i n a l-d u c c i [8] designed a criterion to evaluate web resources for utilization within the context of scholarly research within the discipline of art history. Key qualitative and quantitative indicators chosen to assess the efficiency of the activity of the organization and e-Learning efficiency indicators are proposed in [9]. On this basis, a neural network model for predicting the efficiency of e-Learning is developed with good accuracy. The accuracy of the neural network prognosis is evaluated by comparison of the obtained outcome indicators of the neural network and the actual values.

The proposed approach for assessing the quality and efficiency of a system is essential both in its overall analysis and improvement.

2.2. Description of the web-based system

The university web-based system has two interfaces. Each of them is user friendly and it is easy and interactive for all users – guests, students, teachers, administrators. The system is flexible and open – independent of the system operation, compatible with the widely used browsers, compatible with other Web applications, plug-ins, etc. It is also independent of the specific discipline content. The system provides quick and easy access to any part of it as well. The students' interface gives the students a possibility of (self-) evaluation of the theoretical

knowledge and a possibility for creation and improvement of their professional skills to solve clinical cases. Using the administrative interface, teachers without programming skills can easily publish lectures as a source of knowledge, interactive tests for (self-) assessment of theoretical knowledge and interactive virtual patients to facilitate the creation of problem-solving skills.

2.3. Stages of implementation

The quality assessment and efficiency of any Web-based system is a specific work and it has to rely on an approved standard in order to escape the subject factors. This paper applies the international standard for evaluation of ISO 9126 software [11]. ISO 9126 is an international standard for the evaluation of software and identifies 6 main quality characteristics, namely:

- Functionality – The *functionality characteristic* allows to draw conclusions about how well the software provides the desired functions.
- Reliability – The *reliability characteristic* allows to draw conclusions about how well the software maintains the level of system performance when used under specified conditions.
- Usability – The *usability characteristic* allows to draw conclusions about how well the software can be understood, learned, used and approved by the developer.
- Efficiency – The *efficiency characteristic* allows to draw conclusions about how well the software provides the required performance, relative to the amount of resources used.
- Maintainability – The *maintainability characteristic* allows to draw conclusions about how well the software can be maintained.
- Portability – The *portability characteristic* allows to draw conclusions about how well the software can be imported from one environment to another.

Each of these quality characteristics consists of several sub characteristics which are shown in Table 1.

The approach proposed for assessing the quality and efficiency of an information system can be applied to various software products in the field of web-based applications, taking into account the specifics of each of them.

First stage. This assessment is done by experts in the field of software engineering (software developer, front-end web developer, web application developer). The list of indicators to assess the quality system based on ISO 9126 standard is determined. After that the weight coefficients are determined. Technological and structural improvement of the system is done based on the obtained results.

Second stage. This assessment is done by teachers from the institution that offers the system. Based on the selected list of didactical indicators, an assessment of the system efficiency is done. The results are processed to make conclusions about the results and make decisions to improve the state of the system.

The proposed system of indicators is open. New indicators can be added or some existing indicators can be excluded according to the specific needs.

Two groups of indicators are defined (Table 1): six indicators for assessing the system quality based on ISO 9126 standard; seven didactical indicators for evaluating the system efficiency.

Table 1. Groups of indicators

Indicators based on ISO 9126 Standard	Didactical indicators
Functionality (Suitability, Accuracy, Interoperability, Security, Functionality Compliance) **Reliability** (Maturity, Fault Tolerance, Recoverability, Reliability Compliance) **Usability** (Understandability, Learnability, Operability, Attractiveness, Usability Compliance) **Efficiency** (Time Behaviour, Resource Utilisation, Efficiency Compliance) **Maintainability** (Analyzability, Changeability, Stability, Testability, Maintainability Compliance) **Portability** (Adaptability, Installability, Co-Existence, Replaceability, Portability Compliance)	Degree of logical consistency of the content Connectivity of the components of the content Encouraging critical thinking and creativity Relation to other resources for further information on studying the problem Use of various multimedia components Existence of a glossary of terms used in the lectures Presence of search engine core modules

One of the most common approaches used to determine the weight coefficients of the indicators is the method of expert assessments. It is based on interviews with experts in a particular problem area and processing results.

Based on the method of expert assessment [10], the approach proposed follows several steps:

- Learning process and choice of indicators of quality and efficiency of the system.
- Determine the degree of competence of the interviewed persons.
- Drawing up of questionnaires, which include:
    - List of indicators (characteristics) for assessing the quality and efficiency of the system;
    - Four fields from a check box type, in which each interviewee gives his/her assessment (Scale: I cannot decide = 0, Low = 2, Good = 4, Strong=6) and one text field, in which the interviewee gives his/her opinion or recommendation;
    - Information competency and source of argument between experts participating in the interviews.
- Determining the circle of specialists and conducting interviews;
- Create a table that includes the opinions and assessments of the interviewed.
- Calculation of the coefficient of agreement between interviewees and verification of its importance.
- Calculation of the weight coefficients of the indicators of quality and efficiency.
- Processing the results and their graphical representation by diagrams.

For each indicator of the questionnaire, corresponding points are calculated based on the following ratio: $\frac{100\%}{x}$, where x is the corresponding number to the attributes of individual indicators. Considering the preset scale (Scale: Low = 2, Good = 4, Strong = 6; I cannot decide = 0), the results of the calculations are entered in a table and visualized by a pie-chart for each indicator.

The competence of the experts is determined by the expression

(1) $$C = \frac{a_1+a_2+a_3}{R}$$

where R is the number of experts.

The coefficients a_1, a_2, a_3 are determined by the position given by expert, the experience in years of work in the field of software technology and the source of argumentation.

2.4. Calculation of the weight coefficients of various parameters

In this example R available experts are invited to give their opinion about m target parameters by a questionnaire sheet. The results are recorded in the weight matrix (Table 2). Each number in the weight matrix a_{ij} determines the weight (assessment), which the expert i ascribes to the target parameter (indicator) j.

Table 2. Weight matrix

Experts	Ex_1	Ex_2	Ex_3	….	Ex_i	….	Ex_R	S_j	$S_{j\text{av}}$	δ_j	V_j	W_j
Indicators												
y_1	a_{11}	a_{21}	a_{31}	….	a_{i1}	….	a_{R1}	S_{i1}	$S_{i\text{av}1}$	δ_1	V_1	W_1
y_2	a_{12}	a_{22}	a_{32}	….	a_{i2}	….	a_{R2}	S_{i2}	$S_{i\text{av}2}$	δ_2	V_2	W_2
….	….	….	….	….	….	….	….	….	….	….	….	….
y_j	a_{1j}	a_{2j}	a_{3j}	….	a_{ij}		a_{Rj}	S_{ij}	$S_{i\text{av}j}$	δ_i	V_j	W_j
….	….	….	….	….	….	….	….	….	….	….	….	….
y_m	y_{1m}	y_{2m}	y_{3m}	….	y_{im}	….	y_{Rm}	S_{im}	$S_{i\text{av}m}$	δ_m	V_m	W_m

- The calculation of the amount of the assessments of all experts S_j of each indicator is done by

(2) $$S_j = \sum_{j=1}^{R} a_{ij}$$

where a_{ij} is the evaluation of i-th expert on the importance of j-th indicator, R – number of experts.

- Calculation of the average amount of the group of experts S_{jav} for each indicator by

(3) $$S_{j\text{av}} = \frac{1}{R}\sum_{j=1}^{R} a_{ij}.$$

- Calculation of the average amount of all points (ranks) S_{av} [10]:

(4) $$S_{\text{av}} = \frac{R(m+1)}{2}.$$

- To determine the degree of agreement of the views of expert's deviation, δ_j is defined by

(5) $$\delta_j = S_j - S_{\text{av}}.$$

- Calculation of the coefficient of agreement w_k, proposed by Maurice Kendall (see [10]):

$$w_k = \frac{12\sum_{j=1}^{m}\delta_j^2}{R^2(m^3-m)}. \tag{6}$$

- Calculation of the coefficient of variation V_j, characterizing the agreement of assessments of the experts participating in the survey, the importance of the individual parameters:

$$V_j = \frac{(Rm-S_j)}{Rm-R}. \tag{7}$$

As the value of V_j is higher, the degree of agreement of experts' opinions is low and vice versa.

- If there is an agreement in the subjective views of the experts, the weight is calculated by

$$W_j = \frac{V_j}{\sum_{j=1}^{m}V_j}. \tag{8}$$

The results are displayed graphically by the diagrams given below.

3. Results of an experimental application of the proposed approach to quantify the quality of the system performance based on ISO 9126 standard

In this application R = 15 available experts are invited to give their opinion and assessment of the quality of an information system, taking into consideration m = 6 target parameters by a questionnaire sheet. For each indicator of the questionnaire, corresponding points are calculated based on the following ratio: $\frac{100\%}{x}$, where $\boldsymbol{x}$ is a corresponding number to the attributes of the individual indicators. Considering the preset scale (Scale: Low = 2, Good = 4, Strong = 6; I cannot decide = 0), the results of the calculations are entered in tables, individually for each experts (for example Table 3), and visualized by a pie-chart (Fig. 1) for each indicator. The results are recorded in the weight matrix (Table 4) and visualized by a column-chart (Figs 2 and 3). The aim is to optimize the system based on the results.

Table 3. Results of expert 1

Scale / Indicators	Low	Good	Strong	I cannot decide	Points
Functionality	–	20%	60%	20%	4.4
Reliability	–	25%	75%	–	5.5
Usability	–	40%	60%	–	5.2
Efficiency	–	33.33%	66.66%	–	5.333
Maintainability	–	20%	80%	–	5.6
Portability	–	40%	40%	20%	4

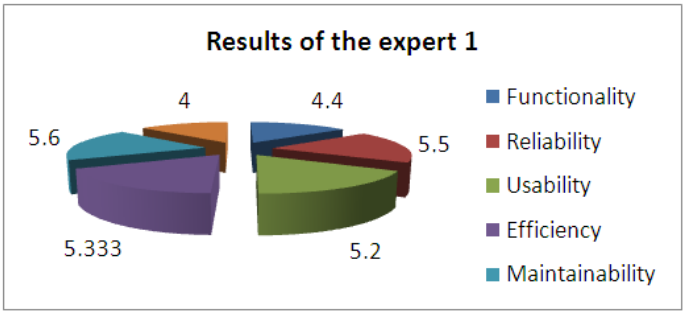

Fig. 1. Results of expert 1

The results of the survey are given in Table 4. The average amount of all points (ranks) is: $S_{\text{av}} = \frac{R(m+1)}{2} = \frac{15(6+1)}{2} = 52.5.$

Table 4. Weight matrix

Experts / Indicators	Ex_1	Ex_2	Ex_3	Ex_4	Ex_5	Ex_6	Ex_7	Ex_8	Ex_9	Ex_{10}	Ex_{11}	Ex_{12}	Ex_{13}	Ex_{14}	Ex_{15}	S_j	S_{jav}	δ_j	V_j	W_j
Functionality	4.4	5.6	6	6	5.6	6	6	5.2	4.8	3.2	3.2	3.2	3.2	5.6	5.2	73.20	4.88	20.70	0.22	0.13
Reliability	5.5	5.5	3	4	5.5	6	5	4.5	4.5	2	3.5	3	5	0	4.5	61.50	4.10	9.00	0.38	0.22
Usability	5.2	5.6	6	5.6	5.6	5.6	6	5.6	5.2	5.2	4.4	4	4.4	5.2	4.4	78.00	5.20	25.50	0.16	0.09
Efficiency	5.333	5.333	4.666	4	5.999	5.333	5.999	4	2.666	2.666	2.666	4.666	4.666	2	2.666	62.66	4.18	10.16	0.36	0.21
Maintainability	5.6	5.6	3.6	5.2	5.6	5.6	5.2	4.4	3.2	2.4	2.4	2.8	3.6	1.6	5.2	62.00	4.13	9.50	0.37	0.22
Portability	4	5.6	2.4	5.6	6	5.6	6	5.2	4.8	5.2	4	2.8	5.2	6	5.6	74.00	4.93	21.50	0.21	0.12

The results, recorded in the weight matrix (Table 4) are visualized by a column-chart below.

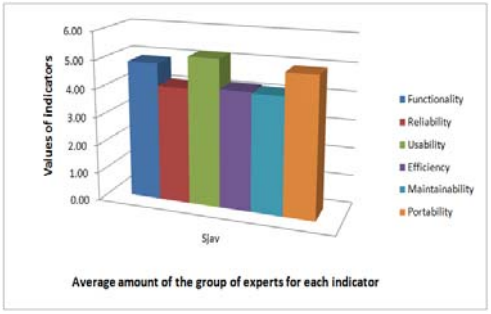

Fig. 2. Results of S_{jav}

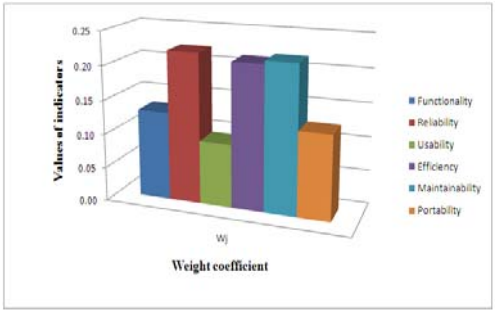

Fig. 3. Results of weight coefficient

The calculation of S_j according to (2), $S_{j\text{av}}$ according to (3) and δ_j according to (5) is based on the data in Table 4 (the right fifth column). The results are shown in the same table. The calculated average amount of the group of experts for each indicator is presented in Fig. 2. The coefficient of agreement using (6) is obtained as:

$$W_k = \frac{12\sum_{j=1}^{m}\delta_j^2}{R^2(m^3-m)} = \frac{12\times 96.36^{\,2}}{15^2(6^3-6)} = 2.36.$$

The weight coefficient W_j is calculated by (8), where V_j is the coefficient of variation, characterized by the agreement of assessments of the experts and it is calculated by (7). The results are shown in Table 4. The calculated weight coefficients W_j are presented in Fig. 3. The aim of the approach proposed is to show the developer on what characteristics should be focused in the future to improve system performance. Bigger values mean that the indicator has to be improved because the weight coefficient (vertical axis) shows difference of the common experts' opinion. The results indicate that the system has to be optimized with respect to reliability, efficiency and maintainability.

4. Results of an experimental application of the proposed approach to quantify the efficiency of the system performance based on Didactical indicators

In this application $\boldsymbol{R}$=13 available experts (teachers) are invited to give their opinion and assessment of the efficiency of an information system, taking into consideration $\boldsymbol{m}$=7 target parameters by a questionnaire sheet. For each indicator of the questionnaire, corresponding points are calculated based on the following ratio: $\frac{100\%}{x}$, where $\boldsymbol{x}$ is the corresponding number to the attributes of individual indicators. Considering the preset scale (Scale: Low = 2, Good = 4, Strong = 6; I cannot decide = 0), the results of the calculations are entered in tables, individually for each experts (for example Table 5), and visualized by a pie-chart (Fig. 4) for each indicator. The results are recorded in the weight matrix (Table 6) and visualized by a column-chart (Figs 5 and 6).

Table 5. Results of teacher 8

Scale / Indicators	Low	Good	Strong	I cannot decide	Ppoints
Degree of logical consistency of the content	–	–	100%	–	6
Connectivity of the components of the content	–	–	100%	–	6
Encouraging critical thinking and creativity	–	–	100%	–	6
Relation to other resources for further information on studying the problem	–	100%	–	–	4
Use of various multimedia components	–	100%	–	–	4
Existence of a glossary of terms used in the lectures	–	–	100%	–	6
Presence of search engine core modules	–	–	100%	–	6

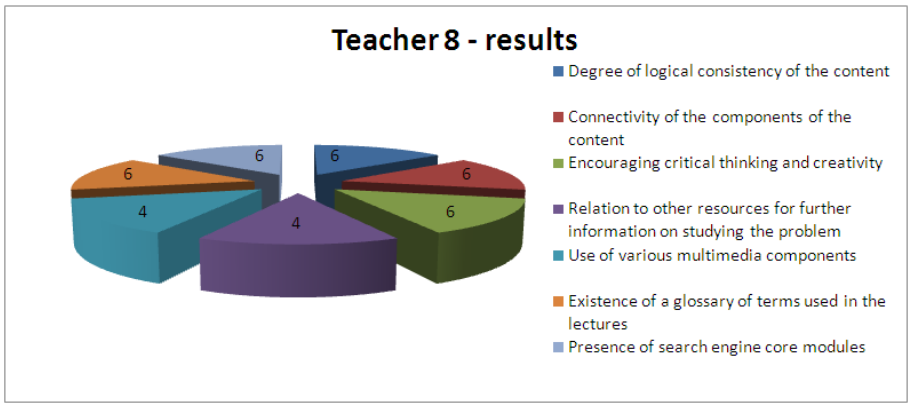

Fig. 4. Results of teacher 8

The results of the survey are given in Table 6. The average amount of all points (ranks) is: $S_{\text{av}} = \frac{R(m+1)}{2} = \frac{13(7+1)}{2} = 52.$

Table 6. Weight matrix

Experts / Indicators	Ex_1	Ex_2	Ex_3	Ex_4	Ex_5	Ex_6	Ex_7	Ex_8	Ex_9	Ex_{10}	Ex_{11}	Ex_{12}	Ex_{13}	S_j	S_{jav}	δ_j	V_j	W_j
Degree of logical consistency of the content	6	6	6	6	6	6	6	6	6	6	6	4	6	76.00	5.85	24.00	0.19	0.13
Connectivity of the components of the content	6	6	6	6	6	6	6	6	6	6	4	6	6	76.00	5.85	24.00	0.19	0.13
Encouraging critical thinking and creativity	6	6	6	6	6	6	4	6	6	4	6	6	6	74.00	5.69	22.00	0.22	0.15
Relation to other resources for further information on studying the problem	6	6	6	6	6	6	6	4	4	4	4	4	6	68.00	5.23	16.00	0.29	0.20
Use of various multimedia components	6	6	6	6	6	6	4	4	6	6	6	4	6	72.00	5.54	20.00	0.24	0.17
Existence of a glossary of terms used in the lectures	6	6	6	6	6	6	6	6	6	6	6	6	6	78.00	6	26.00	0.17	0.11
Presence of search engine core modules	6	6	6	6	6	6	6	6	6	6	6	6	6	78.00	6	26.00	0.17	0.11

The results, recorded in the weight matrix (Table 6), are visualized by a column chart below.

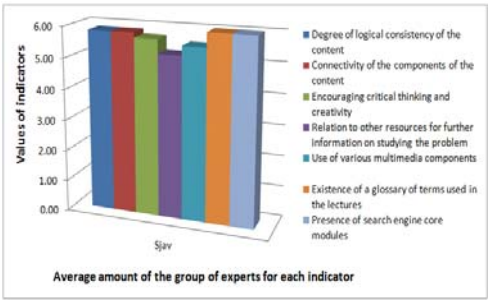

Fig. 5. Results of S_{jav}

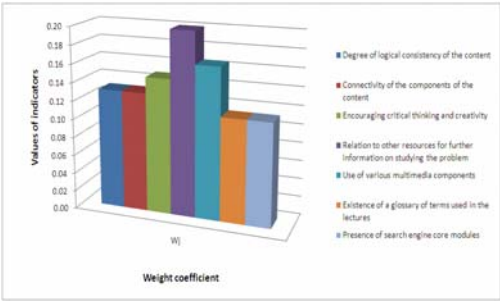

Fig. 6. Results of weight coefficient

The calculations of S_j according to (2), S_{jav} according to (3) and δ_j from (5) are based on the data in Table 6 (the right fifth columns). The results are shown in the

same table. The calculated average amount of the group of experts for each indicator is presented in Fig. 5. The coefficient of agreement using (6) is obtained:

$$w_k = \frac{12\sum_{j=1}^{m}\delta_j^2}{R^2(m^3-m)} = \frac{12.158^{\,2}}{13^2(7^3-7)} = 5.27.$$

The significance of w_k is verified by:

$$\chi^2_{\text{cal}} = R(m-1)w_k = 13(7-1)5.27 = 441.06.$$

In the degrees of freedom $v = m-1=7-1=6$ and level of significance $\alpha = 0.01$ according to [10], the tabulated value of $\chi^2_{tabl.}$ is calculated:

$$\chi^2_{\text{cal}} = 441.06 > \chi^2_{\text{tabl}} = 16.812.$$

The weight coefficient W_j is calculated by (8), where V_j is the coefficient of variation, characterized by the agreement of assessments of the experts and it is calculated by (7). The results are shown in Table 6. The calculated weight coefficients are presented in Fig. 6. The aim of the proposed approach is to show to the developer what characteristics should be focused in the future to improve system's performance. The results indicate that the system has to be optimized in relation to other resources for further information on studying the problem, use of various multimedia components, encouraging critical thinking and creativity.

5. Conclusions

An approach for quality assessment and efficiency of a web-based system for distance learning is proposed. The idea of the presented approach for assessing the quality and efficiency is to optimize the web-based educational system on the basis of the results obtained and to meet the user requirements. The results of the assessment will be used to improve the functionality of the processes in the system to meet the users requirements. This approach can be applied not only to the proposed system but to various web-based software products, taking into account the specifics of each of them.

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